Cover Crops, Herbicides, and Dealing with Herbicide-Resistant Weeds

Bill Curran, Penn State
John Wallace, Cornell University
Herbicide considerations when establishing cover crops and when it is time to terminate

Dr. Bill Curran
Pennsylvania State University
Part 1

- Impact of herbicides on cover crop establishment
Residual Herbicides

- Used in many of our major crops
- Usually soil applied – sometimes POST
- Generally provide 8 to 12 weeks of weed control
- Half-life too short - lack of residual weed control (performance reduced)
- Half life too long - carryover to following crop
  - Very important consideration for some crops and especially those established in late summer/fall
  - Particular consideration if interseeding cover crops in early summer
Carryover Injury to Subsequent Crops Depends On:

• Herbicide **persistence** in soil
  – How long does it last?
  – Herbicide half-life gives us some indication

• Rotational crop **sensitivity/susceptibility**
  – How sensitive are rotational crops - legumes, radish/mustards, grasses

• Persistent herbicides that aren’t very active and short-lived herbicides that are very active don’t really matter
#1 Herbicide Persistence

- **Half-life:** the amount of time needed to degrade half of the herbicide present

**Graph:**

- **Amount remaining (%):**
  - 100%
  - 75%
  - 50%
  - 25%
  - 0%

- **Half life:**
  - 0 days: 100%
  - 1 day: 50%
  - 2 days: 25%
  - 3 days: 12.5%
  - 4 days: 6.25%
  - 5 days: 3.125%
  - 6 days: 1.5625%

**Herbicides and Half-lives:**

- **2,4-D**
  - 7 days
- **Atrazine**
  - 60 days
  - 120 days
  - 180 days
  - 240 days
Herbicide half-life
General Rule

• Short - < 30 days
• Intermediate - 30 –120 days
• Long - > 120 days
Common Herbicide’s Half-Life

- 2,4-D – 7 days
- Atrazine – 15-90 (60) days
- Callisto – 5-50 days
- Dicamba – 14 days
- Dual Mag – 15-50 (35) days
- Impact – 14 days
- Pursuit – 60 – 90 (75) days
- Resolve – 7 days
ADSORPTION

VOLATILITY

LEACHING

PLANT UPTAKE

PHOTO-DECOMPOSITION

CHEMICAL DECOMPOSITION

MICROBIAL DEGRADATION
Geographic/Management Factors That Influence Dissipation Rate

- Soil texture and pH – heavy soil and high pH = last longer
- Consider drought – last longer – long half-life becomes longer
- Application rate - full vs. reduced rates
- PRE vs. POST - time between application and next crop
- Tillage system
  - No-till vs. tilled systems – tillage can dilute residues
- Herbicide combinations – two or more with longer half-lives increases injury potential
## Corn Herbicide Categories

<table>
<thead>
<tr>
<th>≥ 4 months</th>
<th>2-4 months</th>
<th>≤ 2 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Atrazine*</td>
<td>• Accent*</td>
<td>• 2,4-D</td>
</tr>
<tr>
<td>• Balance</td>
<td>• Capreno</td>
<td>• Clarity/Banvel</td>
</tr>
<tr>
<td>• Callisto</td>
<td>• Dual</td>
<td>• Glyphosate</td>
</tr>
<tr>
<td>• Corvus</td>
<td>• Harness/Degree</td>
<td>• Liberty</td>
</tr>
<tr>
<td>• Permit*</td>
<td>• Impact/Armezon</td>
<td>• Harmony</td>
</tr>
<tr>
<td>• Simazine*</td>
<td>• Metribuzin</td>
<td>• Resolve*</td>
</tr>
<tr>
<td>• Stinger/Hornet</td>
<td>• Outlook</td>
<td>• Sharpen</td>
</tr>
<tr>
<td>• Python</td>
<td>• Prowl</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Zidua</td>
<td></td>
</tr>
</tbody>
</table>

*last longer when soil pH > 6.8
## Soybean Herbicide Categories

<table>
<thead>
<tr>
<th>≥ 4 months</th>
<th>2-4 moths</th>
<th>≤ 2 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Authority</td>
<td>• Assure/Targa</td>
<td>• 2,4-D</td>
</tr>
<tr>
<td>• Classic (Canopy etc)*</td>
<td>• Dual</td>
<td>• Glyphosateate</td>
</tr>
<tr>
<td>• FirstRate</td>
<td>• Raptor</td>
<td>• Liberty</td>
</tr>
<tr>
<td>• Pursuit</td>
<td>• Metribuzin</td>
<td>• Harmony</td>
</tr>
<tr>
<td>• Python</td>
<td>• Outlook</td>
<td>• Select</td>
</tr>
<tr>
<td>• Reflex/Flexstar</td>
<td>• Prowl</td>
<td>• Sharpen</td>
</tr>
<tr>
<td>• Scepter</td>
<td>• Valor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Zidua</td>
<td></td>
</tr>
</tbody>
</table>

*Last longer when soil pH > 6.8
Carryover Injury to Subsequent Crops Depends On:

• Herbicide **persistence** in soil
  – How long does it last?
  – Herbicide half-life gives us some indication

• Rotational crop **sensitivity/susceptibility**
  – How sensitive are rotational crops - legumes, radish/mustards, grasses

• Persistent herbicides that aren’t very active and short-lived herbicides that are very active don’t really matter
#2 Crop sensitivity

- Atrazine: alfalfa = clovers > radish = ryegrass/timothy > hairy vetch = pea > oats > wheat = barley = rye
- Mesotrione: clovers = alfalfa > radish > hairy vetch > pea >>>>>>> grasses
- Chlorimuron: clovers = alfalfa > radish > hairy vetch > pea > sorghum > corn >>> cool season grasses
- Imazethapyr: radish > sorghum > hairy vetch > pea > clovers > alfalfa > corn >>> cool season grasses
Herbicide selectivity and persistence demonstration

1 & 2 L bottles – Weed Spray System Equipment
Herbicide selectivity/persistence demo

- Applied herbicides and seeded crops within a day - 6 to 8 species – legumes, grasses, brassicas
- Log sprayer – allows relatively precise dilutions – 100% (1X), 50% (1/2X), 25% (1/4X), 12.5% (1/8X), 6.25% (1/16X)
- Visually evaluated about 4 weeks after seeding (0-100% scale) and used as an educational tool during field day
- Herbicide dilution used as a proxy for half-life
- Half life values taken from the literature
Effect of decreasing Dual Mag rate on cover crop injury (ave. over two years)

(X = 1.67 pt = 1.6 lb)

Half-life = 35 days
Effect of decreasing Pursuit rate on cover crop injury (ave. over two years)

(X = 4 oz = 0.063 lb)

Half-life = 75 days
Effect of decreasing Resolve rate on cover crop injury (ave. over two years)

% Injury

Forage radish
Ryegrass
Hairy vetch
Crimson clover
Oats

Half-life = 7 days
Planning Ahead –
know your herbicide residual

• Check a current Management Guide recrop tables
• Check label for use restrictions – recrop tables
  – Consider particularly sensitive crops – alfalfa, clovers, canola, ryegrass, others
• Look for Half-Life Information
### Table 1-6. Herbicide rotation restrictions for cash crops.

The information listed in this rotation restriction table is our interpretation of label statements or a “best guess” estimate. Consult the label if two or more of these materials are applied during the same season. Herbicide labels are constantly changing; therefore, this list is not a substitute for the most recent herbicide label.

- **AH** = after harvest
- **B** = bioassay of soil recommended before planting
- **NI** = no information
- **NR** = no restrictions
- **NY** = next year
- **SY** = second year following application

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Alfalfa</th>
<th>Cabbage</th>
<th>Clover</th>
<th>Cotton</th>
<th>Cucumber</th>
<th>Field Corn</th>
<th>Grain Sorghum</th>
<th>Lima Bean</th>
<th>Musk melon</th>
<th>Onion</th>
<th>Peanut</th>
<th>Peas</th>
<th>Pepper</th>
<th>Pumpkin</th>
<th>Snap Bean</th>
<th>Soybean</th>
<th>Spring Cot</th>
<th>Squash</th>
<th>Sweet Corn</th>
<th>Tobacco</th>
<th>Tomato</th>
<th>Watermelon</th>
<th>White Potato</th>
<th>Winter Barley</th>
<th>Winter Rye</th>
<th>Winter Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>AH</td>
<td>3</td>
<td>AH</td>
<td>1</td>
<td>AH</td>
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<td>Flexov/Pro</td>
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<td>10</td>
<td>18</td>
<td>NR</td>
<td>NR</td>
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<td>4</td>
<td>4</td>
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</tr>
</tbody>
</table>
Callisto® Label

- Immediate – corn, asparagus, cranberry, millet, grasses grown for seed, oats, and sorghum
- 120 days – small grains
- 10 mo. – alfalfa, canola, cotton, potatoes, soybean, sunflower, tobacco
- 18 mo. – sugar beets, dry beans, peas, cucurbits, red clover, and all other rotational crops
Table 1-6. Corn herbicide half-lives and their potential to injure fall-established cover crops.

This table does not directly address preharvest establishment of cover crops such as interseeding or aerial seeding, which may be more restrictive.

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Common Name</th>
<th>Normal Rate/Acre</th>
<th>Half-life (days)</th>
<th>Fall-established Cover Crops</th>
<th>Concern for</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D 4S</td>
<td>2,4-D</td>
<td>1–2 pt</td>
<td>7</td>
<td>All grasses</td>
<td>Wait 30 days before planting sensitive broadleaves</td>
<td>Amine formulations more water soluble and can leach into seed zone</td>
</tr>
<tr>
<td>Atrazine 4L</td>
<td>atrazine</td>
<td>1–2 qt</td>
<td>15–90</td>
<td>Sorghum species</td>
<td>Cereals, ryegrass, legumes, and mustards</td>
<td>More persistent in high pH soils (&gt; 7); rates &lt; 1 lb/acre can allow more flexibility; half-life in PA probably closer to 30</td>
</tr>
<tr>
<td>Balance Pro 4L/Balance Flexx 2L (Prequel 45WG also contains isoxaflutole)</td>
<td>isoxaflutole</td>
<td>3 fl oz</td>
<td>50–120</td>
<td>Fall cereals grains</td>
<td>Cereals, ryegrass, legumes, and mustards</td>
<td>15 inches of cumulative precipitation required from application to planting rotation crops except soybean, barely, wheat, sorghum, and sunflower</td>
</tr>
<tr>
<td>Callisto (includes Acu-ron, Halex GT, Instigate, Lexar, Lumax, Resicore, Zemax, etc.)</td>
<td>mesotrione</td>
<td>3–6 fl oz</td>
<td>10–50</td>
<td>All grasses</td>
<td>Small-seeded legumes, mustards</td>
<td>Sequential applications (PRE fb POST) increase the potential for injury</td>
</tr>
</tbody>
</table>
General guidelines

- Corn herbicides
  - Atrazine or simazine at < 1 lb/A can allow cereal grain establishment.
    - < 0.75 lb/A may allow for most legume cover crops, mustards, and annual ryegrass.
  - Mesotrione (Callisto, Accuron, etc. is problematic for legumes and mustards like canola and forage radish.
  - Isoxaflutole (Balance, Corvus, Prelude) – legumes and mustards mostly.
  - Clopyralid (Stinger and a component of Hornet, SureStart, Resicore) could also affect these small seeded broadleaves.
Mesotrione-Containing Corn Products

- Callisto
- Acuron
- Acuron Flexi
- Callisto GT
- Callisto Xtra
- Halex GT
- Harness MAX
- Instigate
- Lexar
- Lumax
- Realm Q
- Resicore
- Revulin
- Solstice
- Zemax
General guidelines

• Soybean herbicides
  – Chlorimuron (Classic, etc.), imazethapyr (Pursuit), and fomesafen (Reflex etc.) could be a problem for fall seeded legume or mustard covers - cereal grains OK.

• Wheat herbicides
  – Generally not a problem, except for companion or relay cropping - If you can double-crop soybean, should be OK
Tolerance of interseeded annual ryegrass and red clover cover crops to residual herbicides in mid-Atlantic corn production. Wallace et al. Weed Technol.
Interseeding cover crops requires much more attention.

6 oz Callisto - mesotrione

1.67 pt Dual II Magnum metolachlor
## Grass Herbicides: Risk of Interseeded Cover Crop Injury

<table>
<thead>
<tr>
<th>Potential Biomass Reduction (%)</th>
<th>Low (&lt;15%)</th>
<th>Mod (15-30%)</th>
<th>High (&gt;30%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chloroacetamides (15)</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Dual II Mag 7.64 EC</td>
<td>1.67 pt</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>Zidua 85 WG</td>
<td>2.5 oz</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>Outlook 6 EC</td>
<td>½ pt</td>
<td>½X</td>
<td>PRE</td>
</tr>
<tr>
<td>Outlook 6 EC</td>
<td>1 pt</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>Harness 7 EC</td>
<td>1 pt</td>
<td>½X</td>
<td>PRE</td>
</tr>
<tr>
<td>Harness 7 EC</td>
<td>2 pt</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td><strong>Dinitroanilines (3)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prowl H2O 3.8 CS</td>
<td>1.5</td>
<td>½X</td>
<td>PRE</td>
</tr>
<tr>
<td>Prowl H2O 3.8 CS</td>
<td>3 pt</td>
<td>1X</td>
<td>PRE</td>
</tr>
</tbody>
</table>

### Potential High Risk Products
- **Dual**: Acuron, Bicep/Cinch, Camix, Expert, Halex GT, Lumax/Lexar, Zemax
- **Zidua**: Anthem

https://extension.psu.edu/evaluation-of-residual-herbicides-for-interseeding-in-corn
### Broadleaf Herbicides: Risk of Interseeded Cover Crop Injury

<table>
<thead>
<tr>
<th>Potential Biomass Reduction (%)</th>
<th>Low (&lt;15%)</th>
<th>Mod (15-30%)</th>
<th>High (&gt;30%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broadleaf Herbicides</strong></td>
<td><strong>Product Rate</strong></td>
<td><strong>Label Rate</strong></td>
<td><strong>Appl Timing</strong></td>
</tr>
<tr>
<td>Sulfonylurea (2)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Resolve 25 DF</td>
<td>0.5 oz</td>
<td>½X</td>
<td>PRE</td>
</tr>
<tr>
<td>Resolve 25 DF</td>
<td>1 oz</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>Triazines (5)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Atrazine</td>
<td>1 pt</td>
<td>½X</td>
<td>PRE</td>
</tr>
<tr>
<td>Atrazine</td>
<td>2 pt</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>Atrazine</td>
<td>3 pt</td>
<td>1½X</td>
<td>PRE</td>
</tr>
<tr>
<td>Metribuzin</td>
<td>4 oz</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>PPOs (14)</td>
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<td></td>
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</tr>
<tr>
<td>Sharpen</td>
<td>1.5 fl oz</td>
<td>½X</td>
<td>PRE</td>
</tr>
<tr>
<td>Sharpen</td>
<td>3 fl oz</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>HPPDs (27)</td>
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</tr>
<tr>
<td>Balance Flex 2 SC</td>
<td>5.3 fl oz</td>
<td>1X</td>
<td>PRE</td>
</tr>
<tr>
<td>Callisto 4 SC</td>
<td>5.4 fl oz</td>
<td>1X</td>
<td>PRE</td>
</tr>
</tbody>
</table>

**Potential High Risk Products**

- containing **Callisto**: Acuron, Camix, Halex GT, Instigate, Lumax/Lexar, Realm Q, Revulin, Resicore, Zemax
- containing **>1.5 lb atrazine at std rate**: Expert, Bicep/Cinch Magnum, Harness Xtra
Summary – on silt loam soils in the Mid-Atlantic

If Interseeding Annual Ryegrass:
- Avoid programs w/ Dual, Zidua, Prowl
- Use programs based on Harness or Outlook (G15)
- May tank mix Callisto

If Interseeding Legumes:
- Avoid programs w/ Callisto, Balance
- Use programs based on Harness or Outlook (G15)
- May tank mix Dual or Zidua

If Interseeding Mixtures:
- Avoid programs w/ Callisto, Balance, Dual, Zidua, Prowl
- Use programs based on Harness or Outlook
- Use low rates of atrazine (1 – 2 pts/ac) in programs
Part 2

- Impact of herbicide selection and timing on cover crop termination
Herbicide Considerations

• Selecting herbicides that are effective on both cover crops and weeds
  – What if you have emerged glyphosate-resistant horseweed/marestail or waterhemp

• What about residual herbicides?
  – Concerns for spray coverage?
  – Separate application?

• Concern for crop injury with some active’s
  – May require delayed planting after application – what about planting green?
Herbicide Considerations

• Selecting herbicides that are effective on both cover crops and weeds
  – What if you have emerged glyphosate-resistant horseweed/marestail or waterhemp

• What about residual herbicides?
  – Concerns for spray coverage?
  – Separate application?

• Concern for crop injury with some active’s
  – May require delayed planting after application – what about planting green?
Primary Burndown Herbicides

• Glyphosate (Roundup) – Broadleaves and grasses
• Paraquat (Gramoxone) – Broadleaves and grasses
• Glufosinate (Liberty) – Broadleaves and grasses (limited utility)
• PGR’s - 2,4-D and Dicamba (Banvel) and maybe clopyralid (Stinger) – Broadleaves only
Table 2-4. Effectiveness of herbicides for control of common cash or cover crops in spring before corn establishment.

Control ratings:

- 10 = 95–100%
- 9 = 85–95%
- 8 = 75–85%
- 7 = 65–75%
- 6 = 55–65%
- N = less than 55%

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Rate (lb/acre)</th>
<th>Alle</th>
<th>Alfalfa²</th>
<th>Bluegrass/Timothy²</th>
<th>Bromegrass/Orchardgrass/Fescue²</th>
<th>Clover, Crimson</th>
<th>Clover, Red²</th>
<th>Clover, White²</th>
<th>Mustards/Radish/Fapeseed</th>
<th>Ryegrass, Annual</th>
<th>Rye, Cereal</th>
<th>Wheat, Winter</th>
<th>Vetch, Hairy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D ester</td>
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<td>Dandelion</td>
<td>Dock, Curly</td>
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<td>Fleabanes, Annual</td>
<td>Foxtail spp.</td>
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<td>Geranium, Carolina</td>
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</table>
Glyphosate

- Good on all cereal grains and most grasses
- Rates range from 0.375 – 1.5 lb ae/acre depending on species and growth stage
- Fair to good on many broadleaves
  - Weak on legumes
- Apply at 5 to 40 GPA (lower rate for low volume applications)
- Less mature annuals easier to control
- Glyphosate + NIS + AMS most effective
  - Tank-mixtures may reduce activity (particularly higher rate clay-based herbicides). Avoid tank-mixing with certain foliar/liquid fertilizers
Antagonism

Glyphosate (32 fl oz Roundup) vs Glyphosate + 6 oz metribuzin

12 days after application
22 days after application
Sometimes avoid certain tank-mixes or increase the glyphosate rate and apply under optimum conditions

<table>
<thead>
<tr>
<th>Corn – atrazine/simazine</th>
<th>Soybean - metribuzin</th>
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<tbody>
<tr>
<td>Acuron</td>
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<td>Bicep</td>
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<td>FulTime</td>
<td>Trivence</td>
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<td>Keystone</td>
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<td>Lumax/Lexar</td>
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<td>Princep</td>
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</table>
Paraquat

- Currently sold as Gramoxone
- Apply 0.5 to 1.0 lb/acre (2 - 4 pt) based on weed size (1-6 inches)
- Apply in a minimum of 10 GPA water (general rule)
- Use flat fan nozzle tips
- Include appropriate surfactant (NIS or COC)
- Do not spray in suspension-type fertilizers
- Tank-mix with PSII (Group 5) herbicides to increase control (atrazine, metribuzin, etc.)
- “For grass cover crops, apply prior to tillering or after boot stage. Treatments made between tillering and boot stage may not provide complete control”
Gramoxone + metribuzin 11 DAA
Gramoxone
April 17 application

Photo taken May 18
Herbicide Considerations

• Selecting herbicides that are effective on both cover crops and weeds
  – What if you have emerged resistant horseweed or pigweeds

• What about residual herbicides?
  – Concerns for spray coverage?
  – Requires separate application?

• Concern for crop injury with some active’s
  – May require delayed planting after application – negates the planting green concept
Cover crop termination timing effect on soil moisture, soil temperature, and slug populations in PA no-till corn and soybeans

PLANTING GREEN
Heidi Myer, Heather Karsten, John Tooker, Bill Curran, Sjoerd Duiker
Ron Hoover, Steve Groff, Jim Harbach, Joel Myers, Gerard Troisi
Can Cover Crops Impact Residual Herbicide Efficacy?

- No Cover
- Rye
- Rye + Vetch
Can Cover Crops Impact Residual Herbicide Efficacy?

No Cover  Rye  Rye + Vetch
Residual and Contact Type Herbicides

• May lose performance if applying to large/mature cover crops
• Particular problem for hidden weeds or for soil applied herbicide distribution
• Can you see the soil from above the canopy?
• Systemic herbicides less problematic than contact for control of emerged weeds – Can nozzle selection influence performance?
• Apply residual herbicides after burndown if large/dense cover crops are present
Does rye termination timing influence corn herbicide injury potential?

- No definitive PGR herbicide injury observed in our study
- Rainfall and temperature pattern is likely very important
2,4-D burndown - Corn

• PREPLANT – Planting of corn must be delayed a minimum of 7 days after application at rates up to 1 pint and 14 days at rates from 1 to 2 pts. Planting sooner may result in unacceptable crop injury.

• PRE – Apply after corn is planted but before emergence. Seed furrow must be completely closed at application or severe crop injury may result
Dicamba (Clarity or Banvel) burndown - Corn

- Direct contact of Clarity with corn seed must be avoided. If corn seeds are less than 1.5 inches below the soil surface, delay application until corn has emerged.
- PREPLANT and PRE – Apply 16 fl. oz. on medium or fine-textured soils with ≥ 2.5% OM. Use 8 fl. oz. on soils with less than 2.5% OM
- In reduced till, do not apply PRE to soils with less than 2.5% OM until after corn emergence
Special Considerations for Planting Green

• Glyphosate – cover seed and use Roundup Ready if crop emerging
• Paraquat – cover seed and apply before crop emergence
• PGR herbicides - Some injury potential – timing important
  – Enlist (2,4-D) and Xtend (dicamba) Technologies could provide safer PGR-based tank-mixes for burndown
• Other herbicides – Product specific – could be preplant or crop emergence issues
Questions?

Bill Curran
wcurran@psu.edu